OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

May 15, 1974

To: J. W. Burge, Supervising Engineer
Soils and Materials Section

From: E. C. Novak, Jr.

Subject: An Investigation of the Definition of Frost Heave Textured Material. Research Project 70 E-46. Research Report No. R-914.

In accordance with your verbal request, a brief study has been made of gradation specifications for defining frost susceptible soils. The purpose of this study was to determine the adequacy of the definition of frost heave textured material as presented in Section 2.08.08 of the 1973 Standard Specifications for Highway Construction.

The literature indicates that most inorganic soils containing 3 percent or more of grains finer than 0.02 mm in diameter, by weight, are frost susceptible for pavement design purposes. Gravels and well graded sands, especially those which contain 1-1/2 to 3 percent finer than 0.02 mm size, by weight, should be considered as possibly frost susceptible. Uniform sandy soils may have as high as 10 percent of grains finer than 0.02 mm by weight without being frost susceptible. Particles 0.02 mm in diameter are usually considered to be on the borderline between silt and sand size classifications; but in Michigan 0.074 mm (the No. 200 sieve) is used as the dividing line. This means that, except for most dune and beach sands and very clean gravels, most other soil materials used for road construction are frost susceptible to some degree.

The U. S. Corps of Army engineers uses the frost susceptibility criterion shown in Table 1. This table shows that frost heave textured materials cannot be designated simply as frost susceptible or non-frost susceptible because most soils, including graded aggregates such as 22A, are frost susceptible to some degree. It is suggested, therefore, that frost heave textured materials be defined on the basis of how detrimental their frost susceptibility would be to pavement performance.

It is recommended that frost heave textured materials include those which are classified as moderately or more frost susceptible on the basis of the U. S. Corps of Engineers frost susceptibility classification. In this case 2.0 in. or more of heave per foot of frost penetration could be expected for frost susceptible materials and a lesser heave from soils classified as having acceptable frost heave potential.

Extensive studies conducted by the U. S. Corps of Engineers (1) show that within any large gradation classification such as gravels, sands, etc., there are some materials which will exceed the 2.0 in. heave criteria even though, on the average, the soils within the classification may have a much smaller heave potential. This is illustrated in Figures 1 through 6 which show that only clean gravels can be expected to heave less than 2.0 in./ft of frost penetration, with reasonable confidence. On the other hand we might expect that over 20 percent of silty sandy gravel materials falling within the gradation band shown in Figure 2 could be expected to heave over 2.0 in./ft. Gravelly sands, within the gradation band shown in Figure 3, would be expected to contain a smaller percentage of materials whose frost heave potential would exceed 2.0 in./ft. Clayey silty sands, within the gradation band shown in Figure 4, would all be classified as non-frost heave textured materials by the definition used in Section 2.08.08 of the Specification Manual. Figure 4, however, shows that the average material within this gradation band has 1.8 in./ft frost heave potential and that roughly 30 or 40 percent of the materials within this gradation band will exceed 2.0 in./ft frost heave potential. The present specification, then, has a good chance of accepting "dirty" sand soils whose frost heave potential exceeds 2.0 in. The silt and clay gradation ranges shown in Figures 5 and 6, respectively, show that only about 15 percent of the material considered to be silt could have less than 2.0 in./ft frost heave potential, while perhaps 25 percent of clay materials could heave less than 2.0 in./ft.

General estimates of the percentage of material exceeding 2.0 in./ft frost heave potential for each classification group are based on the assumption that values are normally distributed about the mean.

In summary, it can be concluded that soils cannot be considered as "frost susceptible" or "non-frost susceptible" since very few soils can be considered to be non-frost susceptible. Instead, they should be identified as materials whose frost heave potentials will have an unacceptable effect on pavement performance, or those whose frost heave potential is low enough so that detrimental effect on pavement performance is acceptable.

Any frost heave potential can be arbitrarily chosen to represent the dividing line between "acceptable" and "non-acceptable" materials since there is no rational data on which to make such a decision. For this report, a limit of 2.0 in. of frost heave potential per foot of frost penetration was chosen but lesser or greater potentials may have equal or better merit.

On the basis that acceptable materials shall have no more than 2.0 in./ft frost heave potential, our present specification appears to be surprisingly effective. However, a large percentage, an estimated 30 to 40 percent, of "dirty" sand soils may exceed the 2.0 in./ft frost heave potential. Since the maximum frost heave potential of such material is much less than that of silt and clay soil classifications, and because the 2.0 in./ft limit could

be conservative, the risk of accepting a material which will result in premature failure of the pavement may be small enough to be acceptable. However, undesirable materials with this gradation range, as in Figure 4, could be identified in the Research Laboratory by a direct frost susceptibility test thus eliminating guess work which, if wrong, could result in acceptance of materials yielding poor pavement performance.

The silt soils shown in Figure 5 would definitely be excluded by the present specification definition. Clays, however, present another gray area. Twenty of the 29 clay samples tested have frost heave potential in excess of 2.0 in./ft. Of the 20, one-half would be rejected for PI values of 10 or less. On the other hand, 17 would have been rejected if the PI requirement for minus 40 materials were set at 15. In addition, the frost heave potential is not as dependent on the percentage of silt as it is on the combined percentage of silt and clay and the PI of the minus 40 sieve size.

It is recommended that the definition of frost heave textured material, as defined in Section 2.08.08 of the Specification Manual, be modified as follows: substitute "50 percent minus the 200 sieve" for "50 percent silt," and substitute "plasticity index less than 15," for "plasticity index less than 10." It is also suggested that a rapid frost heave test, such as the New Hampshire test, be used to positively determine the frost susceptibility of questionable materials. This could be accomplished by including a requirement that the Engineer may request the material be tested to determine its frost heave potential. The material would be rejected if its potential was 2.0 in./ft or greater, and accepted if less. The direct frost susceptibility test would take precedence over the textural definition in determining material acceptability.

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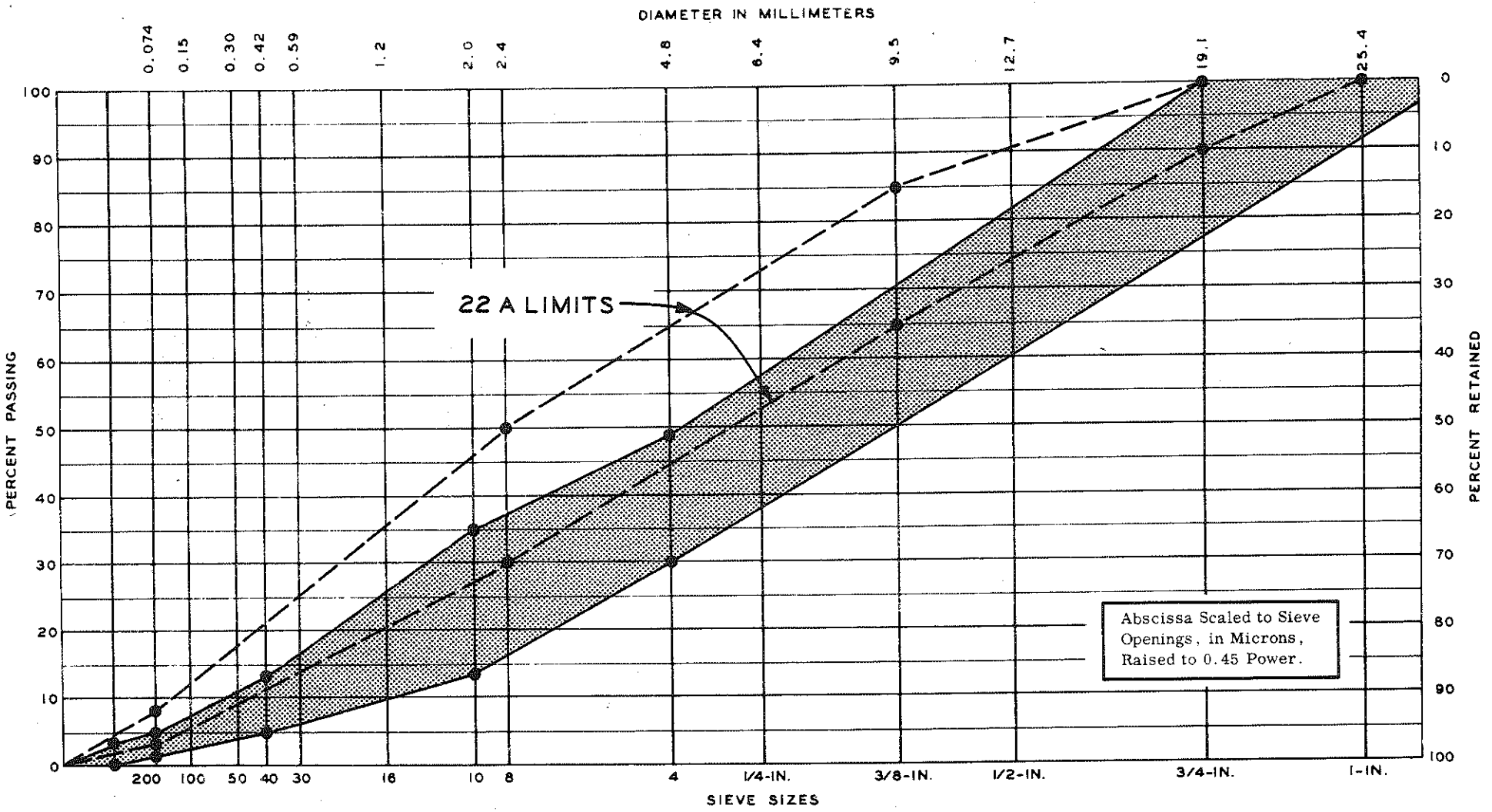
REFERENCE

1. Linell, K. A., Hennion, F. B., Lobacz, E. F., "Corps of Engineers' Pavement Design in Areas of Seasonal Frost," Highway Research Record 33, 1963.

TABLE 1

FROST SUSCEPTIBILITY CLASSES BY CORPS OF ENGINEERS

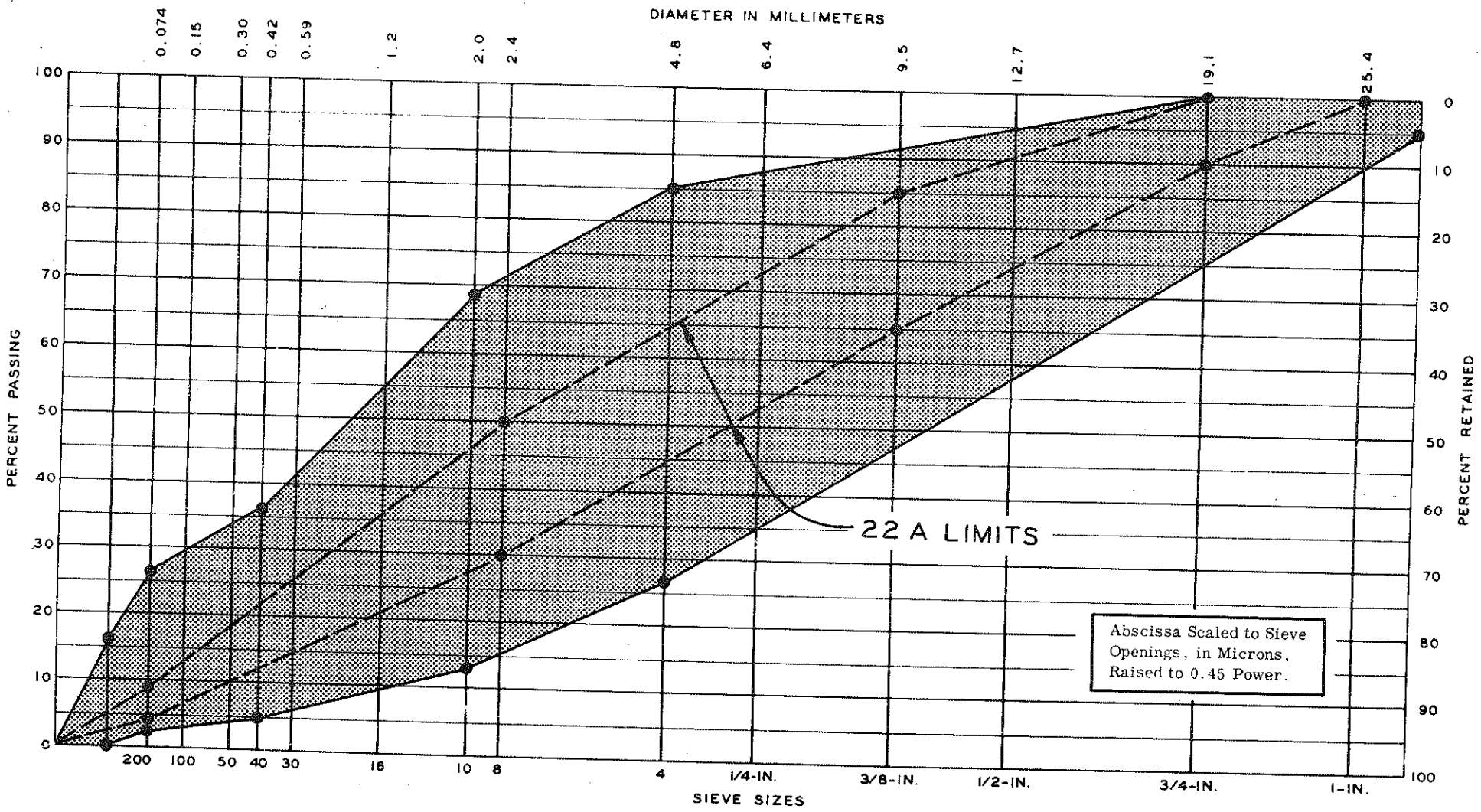
Frost Susceptibility Classification	Corps of Engineers Freeze Test Avg Range of Heave mm/day	Heave Potential, in./ft
Negligible	0-0.5	0-0.5
Very Low	0.5-1.0	0.5-0.9
Low	1.0-2.0	0.9-1.9
Medium	2.0-4.0	1.9-3.8
High	4.0-8.0	3.8-7.6
Very High	> 8.0	7.6



"Average" frost heave potential based on 13 tests within gradation band; in in. of heave/ft frost penetration.

Avg Heave	= 1.0 in./ft	P.I.'s	
High	= 2.1 in./ft	Avg	= 0.5
Low	= 0.1 in./ft	High	= 3
σ	= 0.8 in./ft	Low	= 0

Figure 1. Frost heave potential - clean gravels

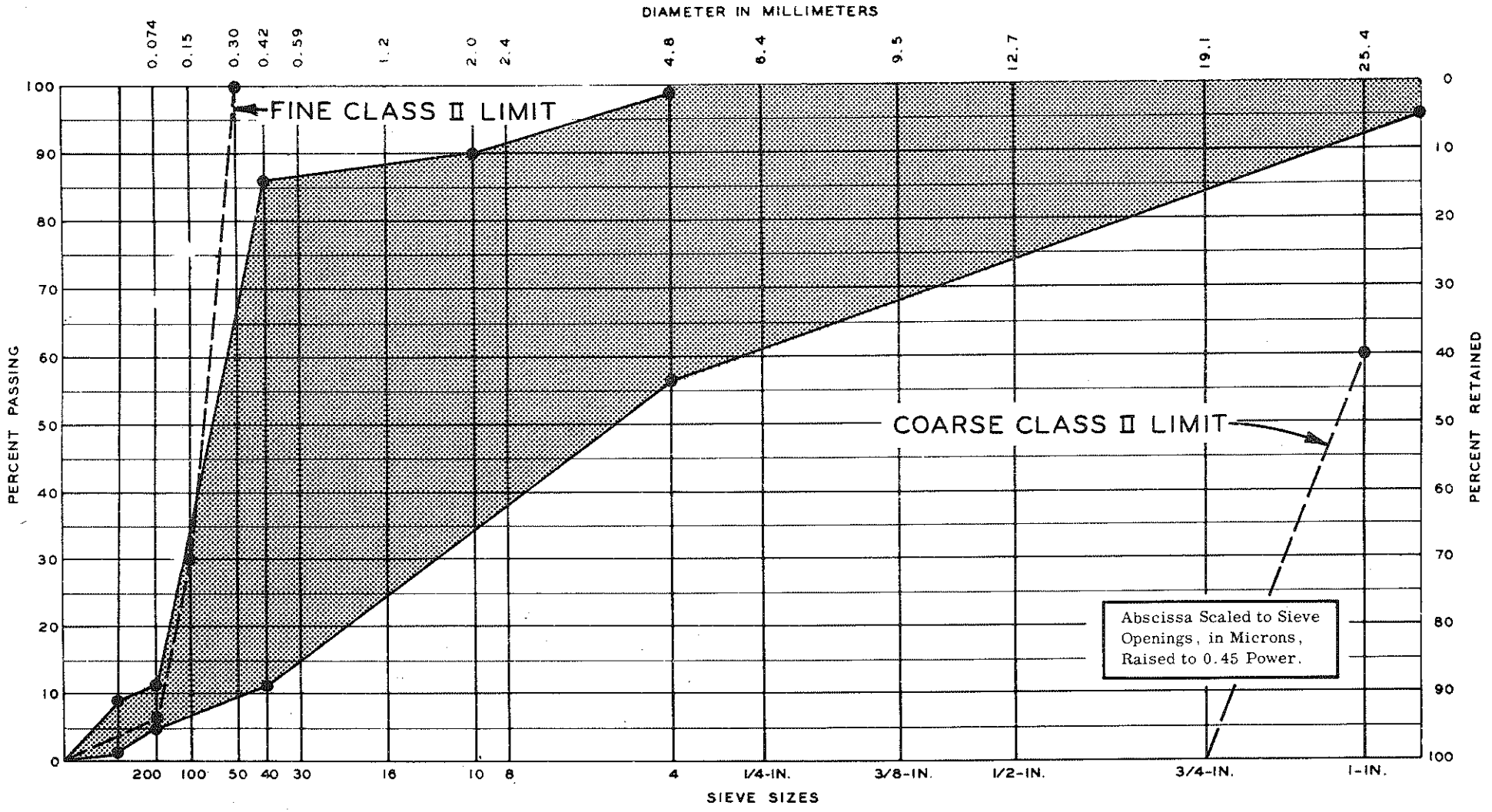


Frost heave potential based on 48 tests within gradation band. Heave in in./ft of frost penetration.

Avg Heave	= 1.7 in./ft
High	= 4.2 in./ft
Low	= 0.1 in./ft
σ	= 1.0 in./ft

P.I.'s
Avg = 1.5
High = 24.6
Low = 0

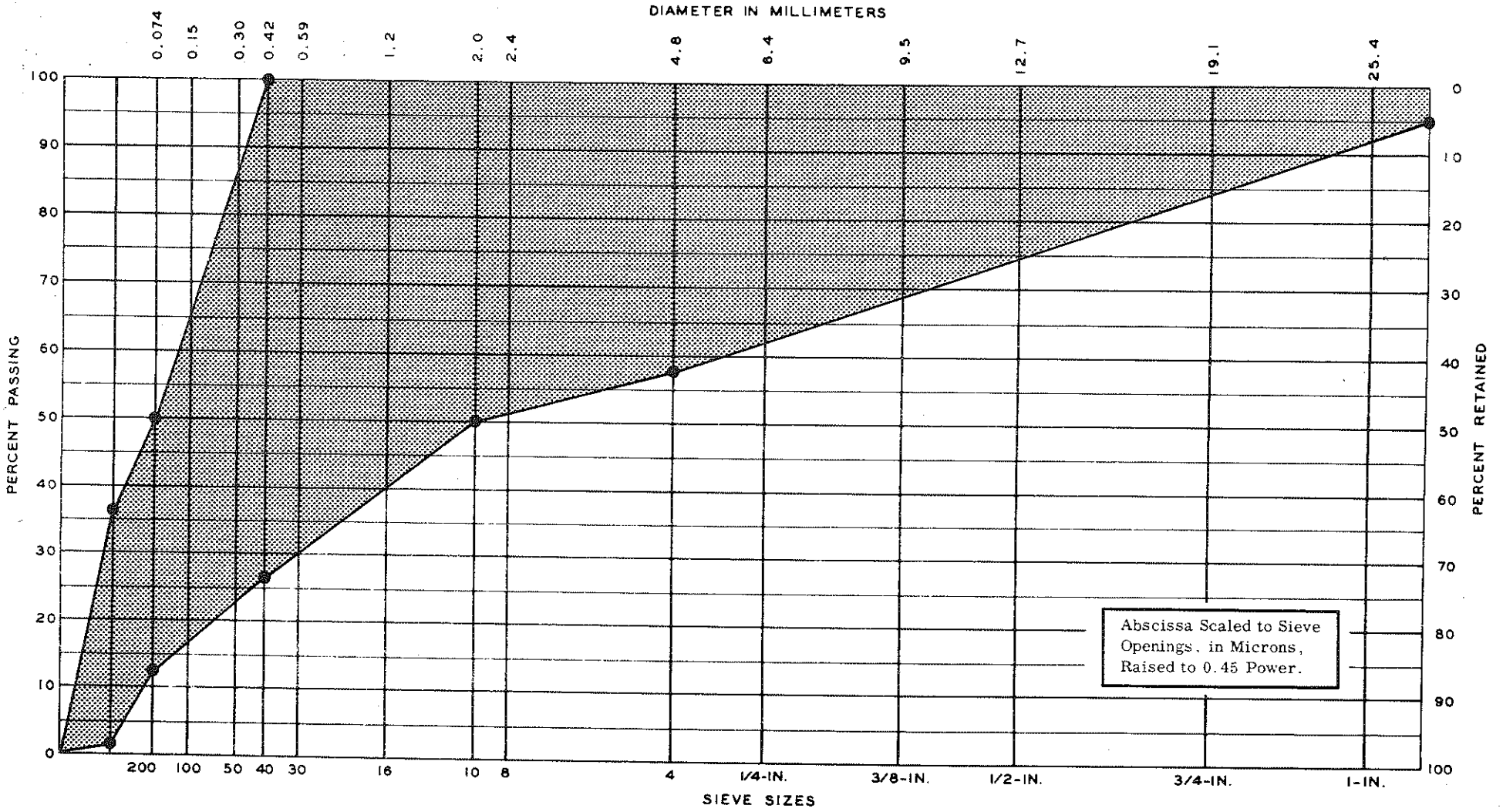
Figure 2. Frost heave potential - silty sandy gravels.



Frost heave potential based on 30 tests within gradation band. Heave in in./ft of frost penetration.

Avg Heave	= 1.2 in./ft	P.I.'s
High	= 6.0 in./ft	Avg = 0.3
Low	= 0.1 in./ft	High = 4.3
σ	= 1.3 in./ft	Low = N.P.

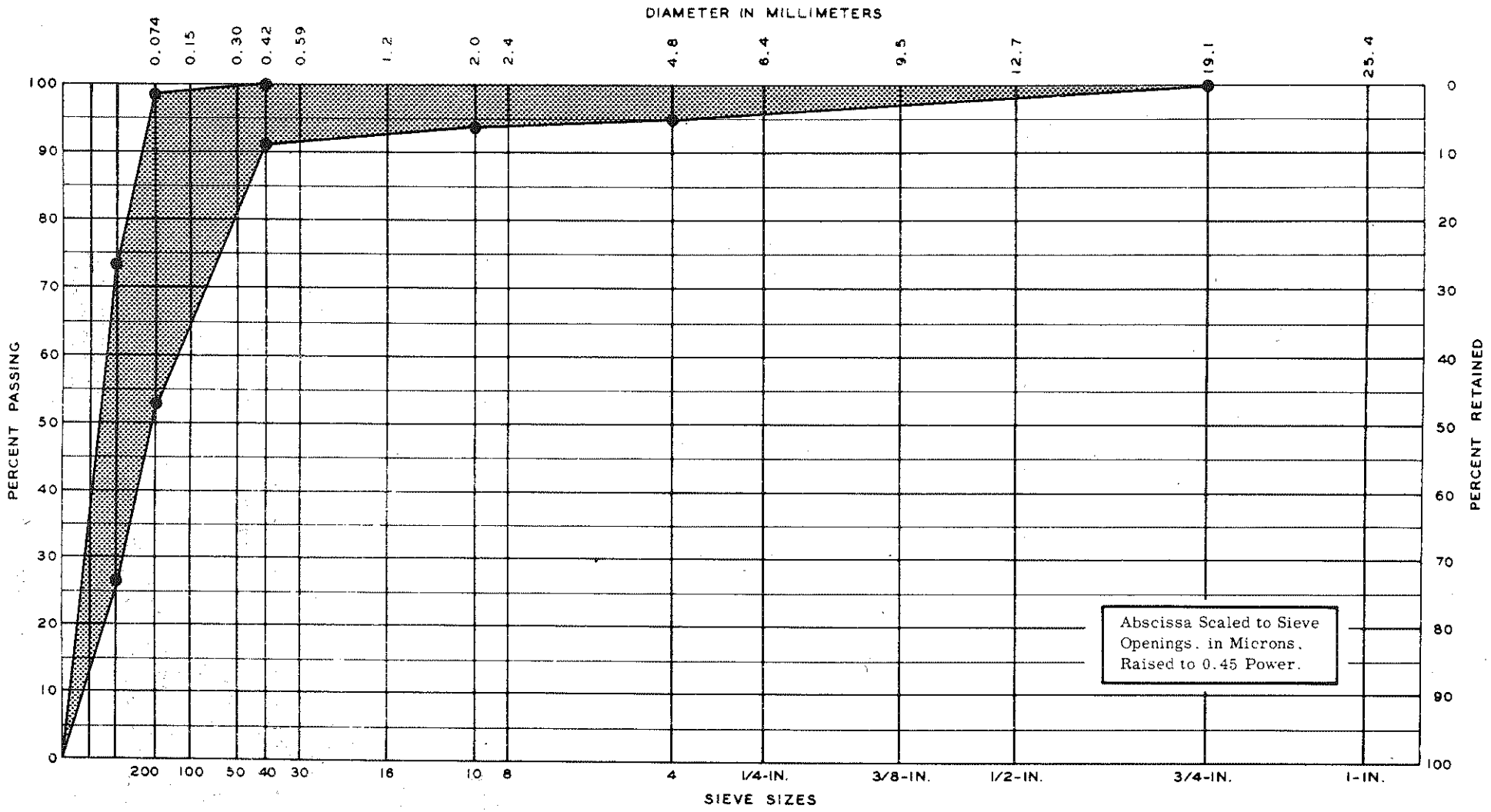
Figure 3. Frost heave potential - gravelly sands.



Frost heave potential based on 51 tests within gradation band. Heave in in./ft of frost penetration.

Avg Heave = 1.8 in./ft	P.I.'s
High = 6.0 in./ft	Avg = 2.7
Low = 0.1 in./ft	High = 11.0
σ = 1.3 in./ft	Low = N.P.

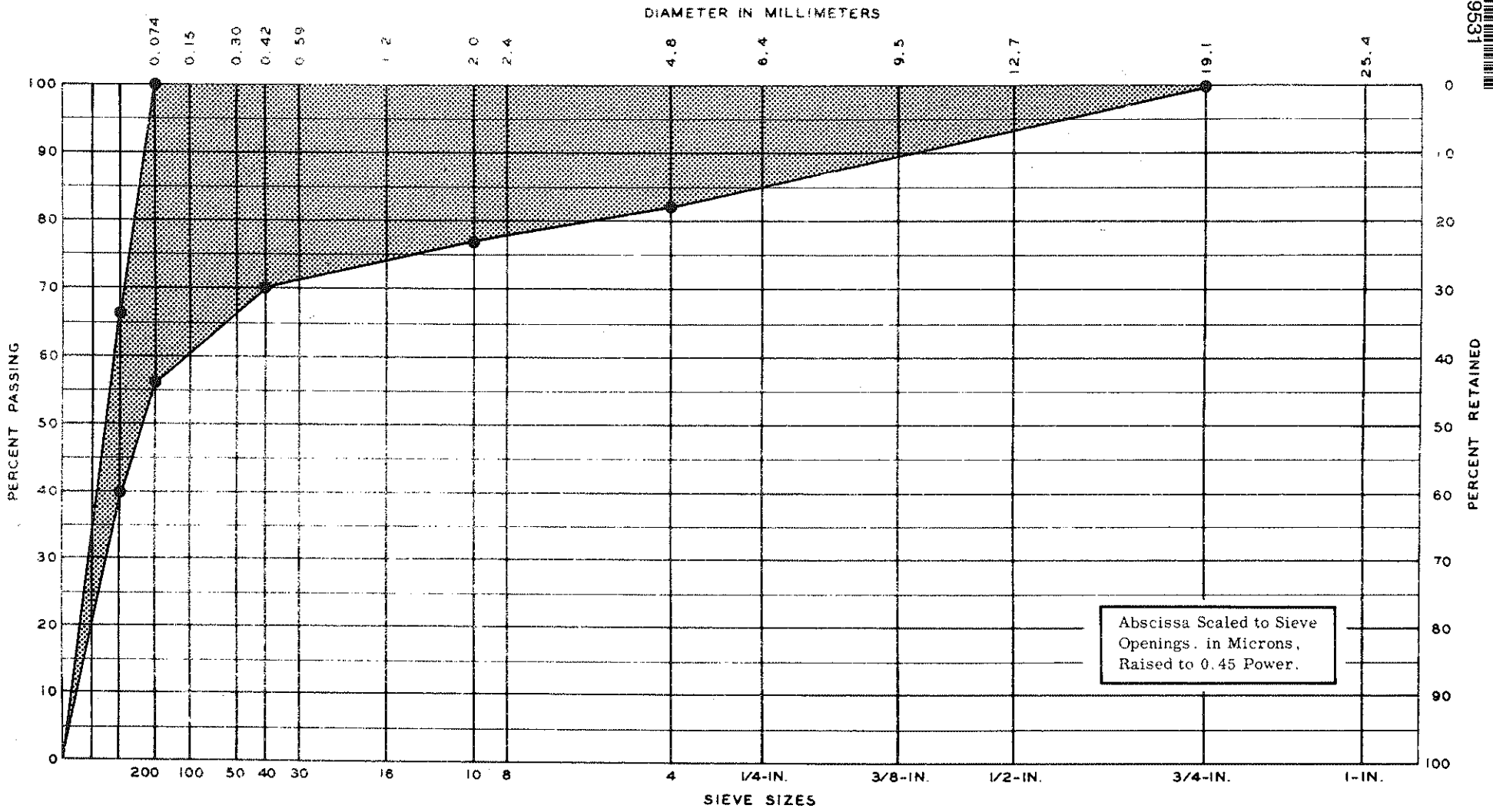
Figure 4. Frost heave potential - clayey silty sands.



Frost heave potential based on 17 tests within gradation band. Heave in in./ft of frost penetration.

Avg Heave	= 8.4 in./ft	P.I.'s	
High	= 24.6 in./ft	Avg	= 3.6
Low	= 1.1 in./ft	High	= 8.1
σ	= 6.9 in./ft	Low	= N.P.

Figure 5. Frost heave potential - silts.



Frost heave potential based on 29 tests within gradation band. Heave in in./ft of frost penetration.

Avg Heave	= 4.0 in./ft	P.I.'s	
High	= 13.2 in./ft	Avg	= 13
Low	= 0.8 in./ft	High	= 37
σ	= 3.0 in./ft	Low	= 7

Figure 6. Frost heave potential - clays.